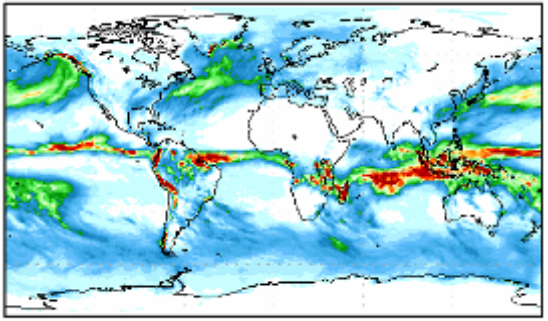
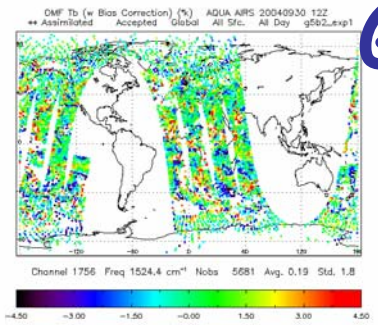
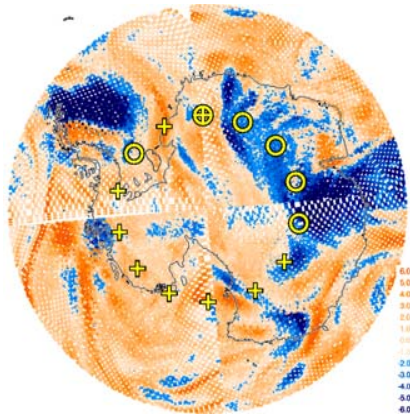


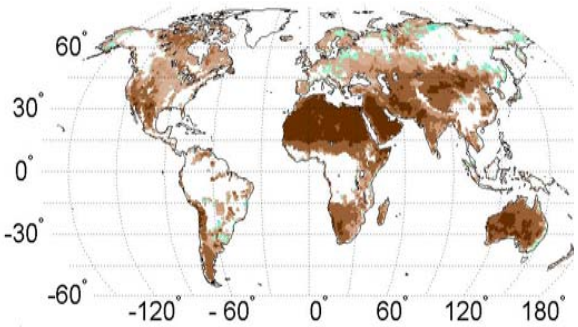


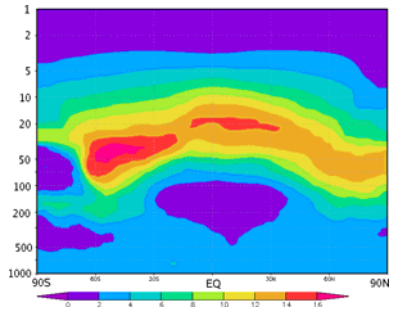
GMAO Satellite Data Assimilation

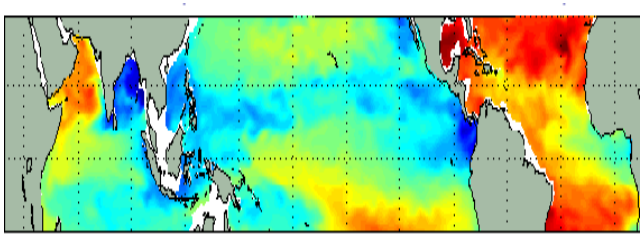


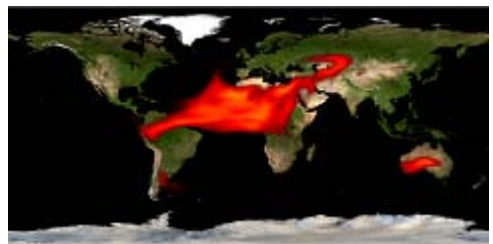
Michele Rienecker
Max Suarez, Ron Gelaro, Ricardo Todling, Emily Liu
Ivanka Stajner, Meta Sienkiewicz, Rolf Reichle
Christian Keppenne, Robin Kovach
Watson Gregg, Lars Nerger

Global Modeling and Assimilation Office (GMAO)
NASA/Goddard Space Flight Center









JCSDA Science Workshop
May 1-2, 2007

Global Modeling & Assimilation Office

http://gmao.gsfc.nasa.gov

Mission: *maximize the impact of satellite observations in climate, weather and air-quality prediction using comprehensive global models and data assimilation.*

- Science areas:
  - Subseasonal-to-Decadal Climate Prediction
  - Weather prediction
  - Chemistry-climate connections
  - Hydrological Cycle
- Technical areas:
  - Satellite data assimilation:- accelerate use of existing satellite data, evaluate existing and new mission observation designs; product generation (support for NASA instrument team products, reanalysis)
  - Model development: use of satellite data to guide new parameterizations; advanced software through ESMF

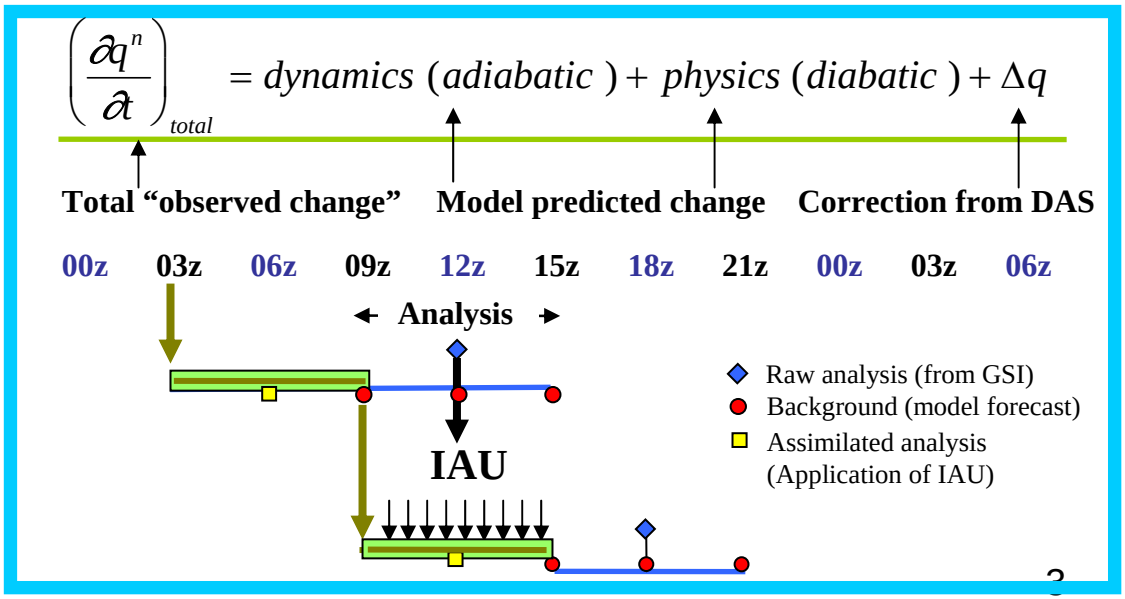
GEOS-5 Atmospheric Data Assimilation System

Ricardo Todling, Max Suarez, Larry Takacs, Emily Liu

- **AGCM**
  - Finite-volume dynamic core
  - Bacmeister moist physics
  - Physics integrated under the Earth System Modeling Framework (ESMF)
  - Catchment land surface model
  - Prescribed aerosols
  - Interactive ozone

- **Analysis**
  - Grid Point Statistical Interpolation (GSI)
  - Direct assimilation of satellite radiance data
  - JCSDA Community Radiative Transfer Model (CRTM) for most current instruments in space
  - GLATOVS for TOVS (HIRS2, MSU, SSU) on board of TIROS-N, NOAA-06,…, NOAA-12
  - Variational bias correction for radiances

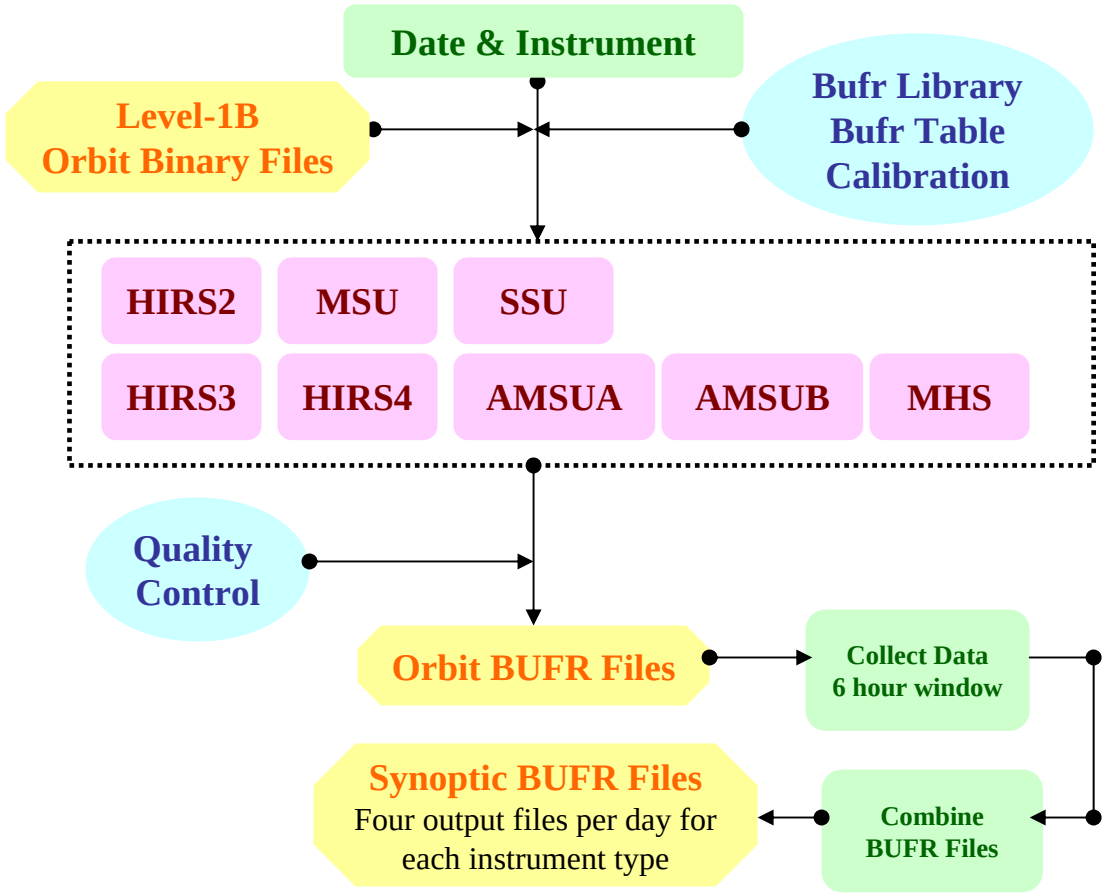
- **Assimilation**
  - Apply Incremental Analysis Increments (IAU) to reduce shock of data insertion
  - IAU gradually forces the model integration throughout the 6 hour period



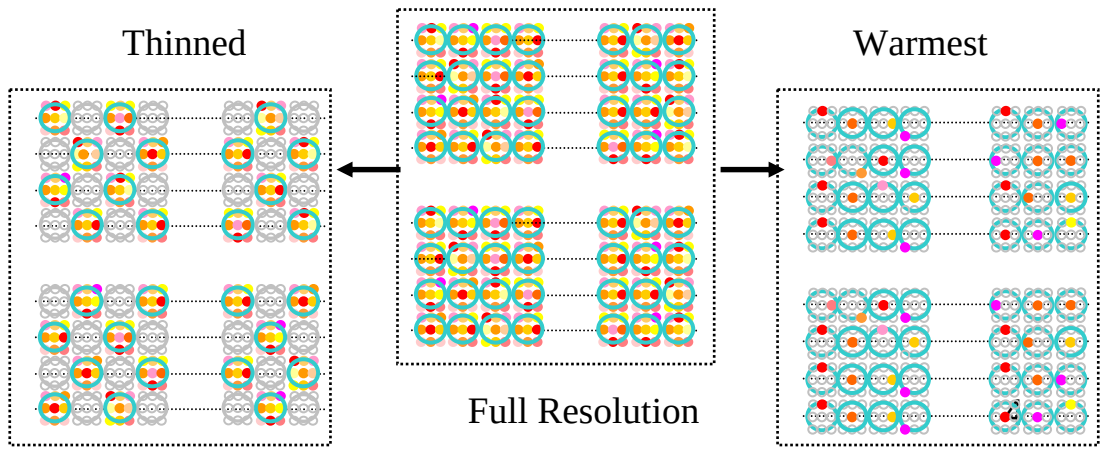
In-house Radiance Data Processing

Emily Liu

- In house data processing to support Modern Era Retrospective-analysis for Research and Applications (MERRA)
- Level-1b TOVS/ATOVS radiance data were converted to calibrated radiance in BUFR format with appropriate quality controls
- Data available from 1979 to current
- Data blacklists from ECMWF ERA40, JMA25 reanalysis, and GMAO GEOS-4 reanalysis (CERES) for further data screening
- Can reprocess the radiance data if calibration coefficients can be estimated from a better techique such as SNO (simutaneous nadir overpass)



- Receiving full spatial resolution AIRS and AMSU-A data from NESDIS
- Processing full resolution data set into thinned and warmest data sets in BUFR format



MERRA

http://gmao.gsfc.nasa.gov/merra/

Michael Bosilovich, Siegfried Schubert & Gi-Kong Kim

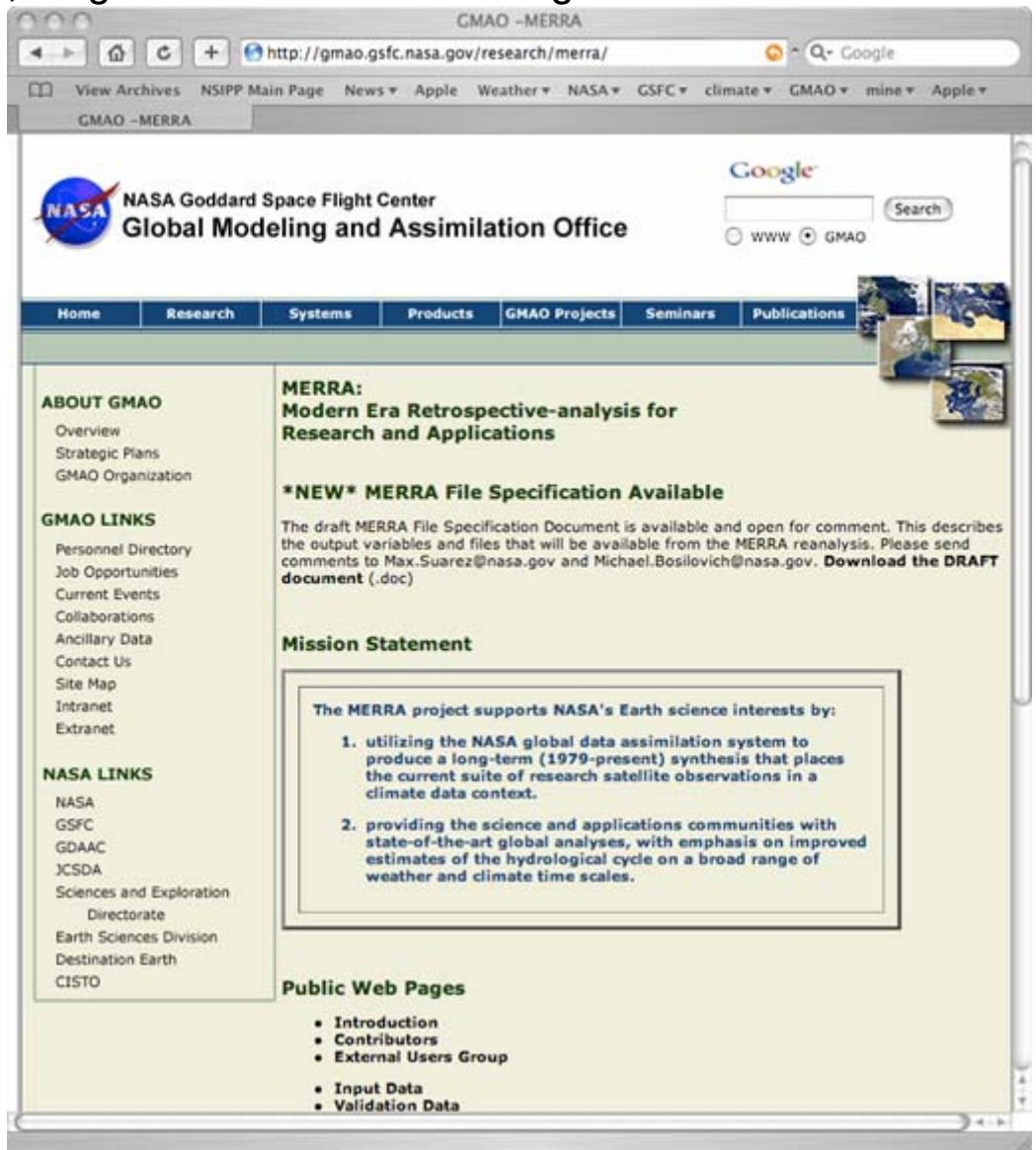
MERRA System

1/2° × 2/3° × 72L to .01 mb
1979-present
GSI Analysis with IAU
Parallel AMIP run

EMPHASIS ON WATER CYCLE
- Global Precipitation, Evaporation, Land Hydrology, Cloud parameters and TPW

GLOBAL HEAT AND WATER BUDGETS FOR ALL PROCESSES

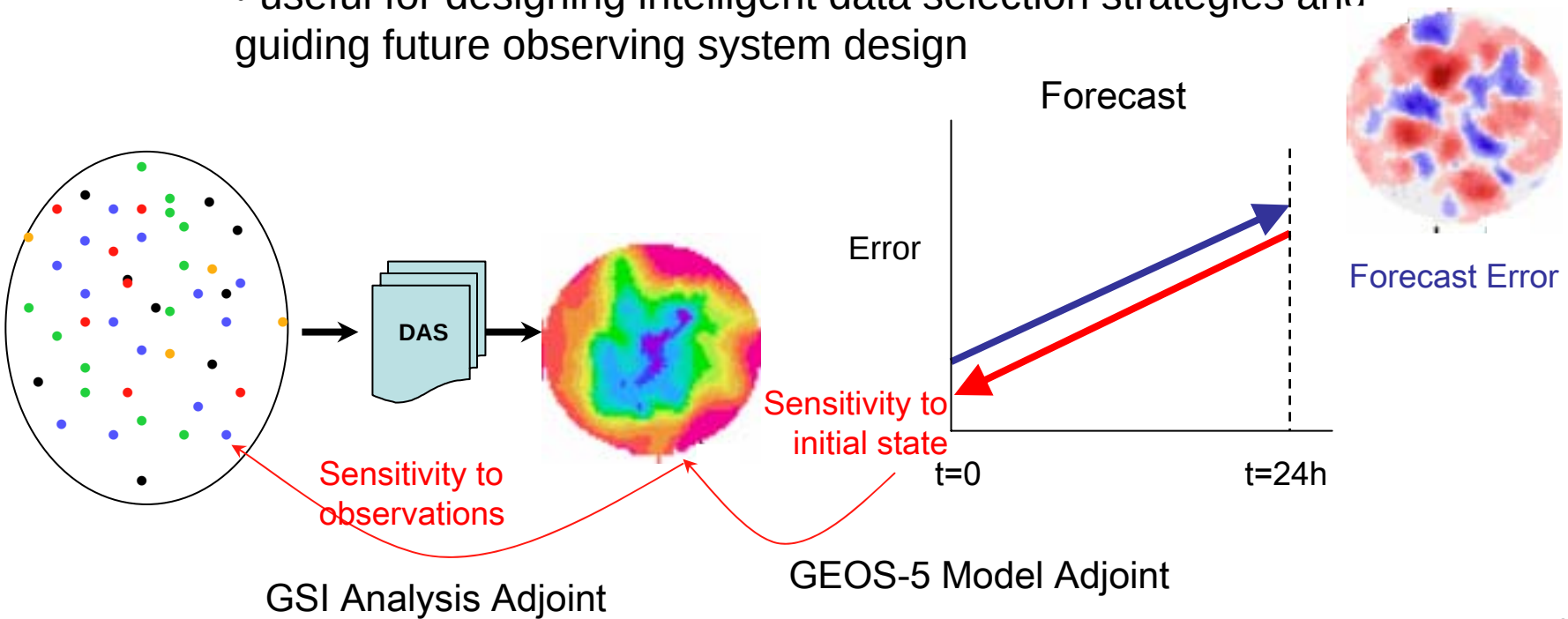
DIURNAL CYCLE FROM HOURLY 2-D FIELDS



Adjoint tools for Observation Impact Studies

Ron Gelaro

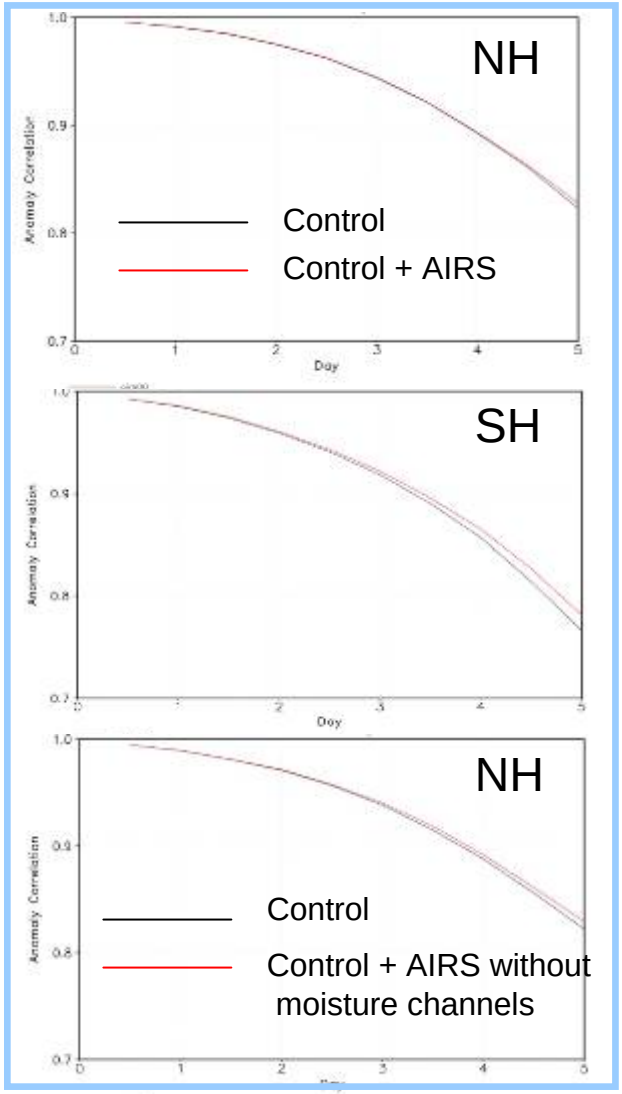
- Efficient estimation of sources of forecast error and observation sensitivity (observation impact)
  - determined with respect to observational data, background fields or assimilation parameters, all computed simultaneously
  - useful for designing intelligent data selection strategies and guiding future observing system design

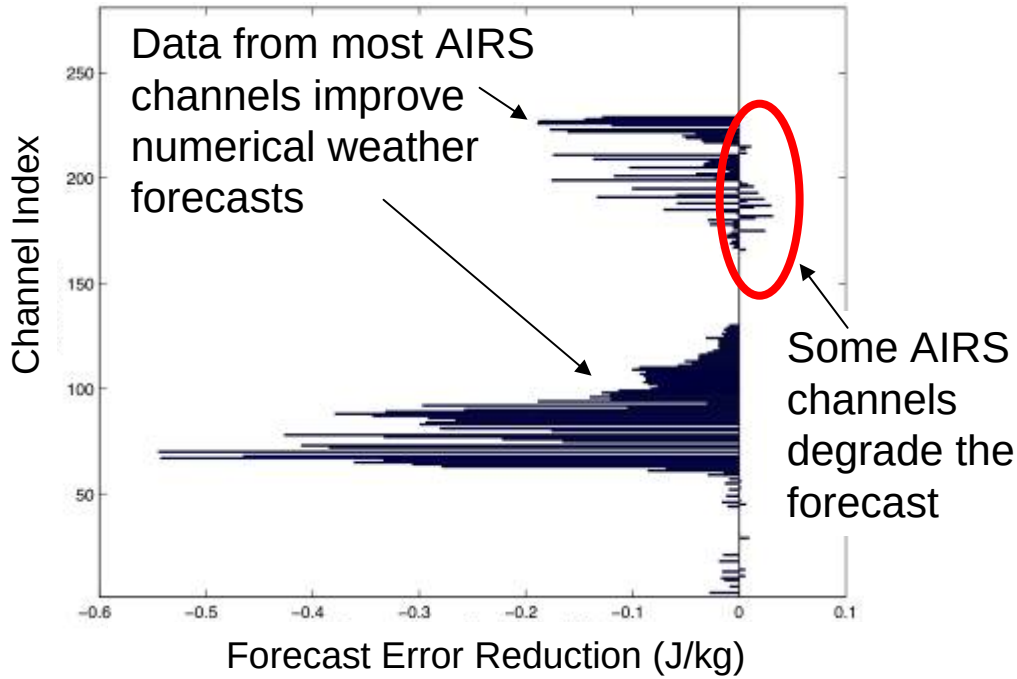


GEOS-5 used to Evaluate Impact of AIRS in NWP

Emily Liu, Ron Gelaro, Yanqiu Zhu

Forecast Skill vs. Time



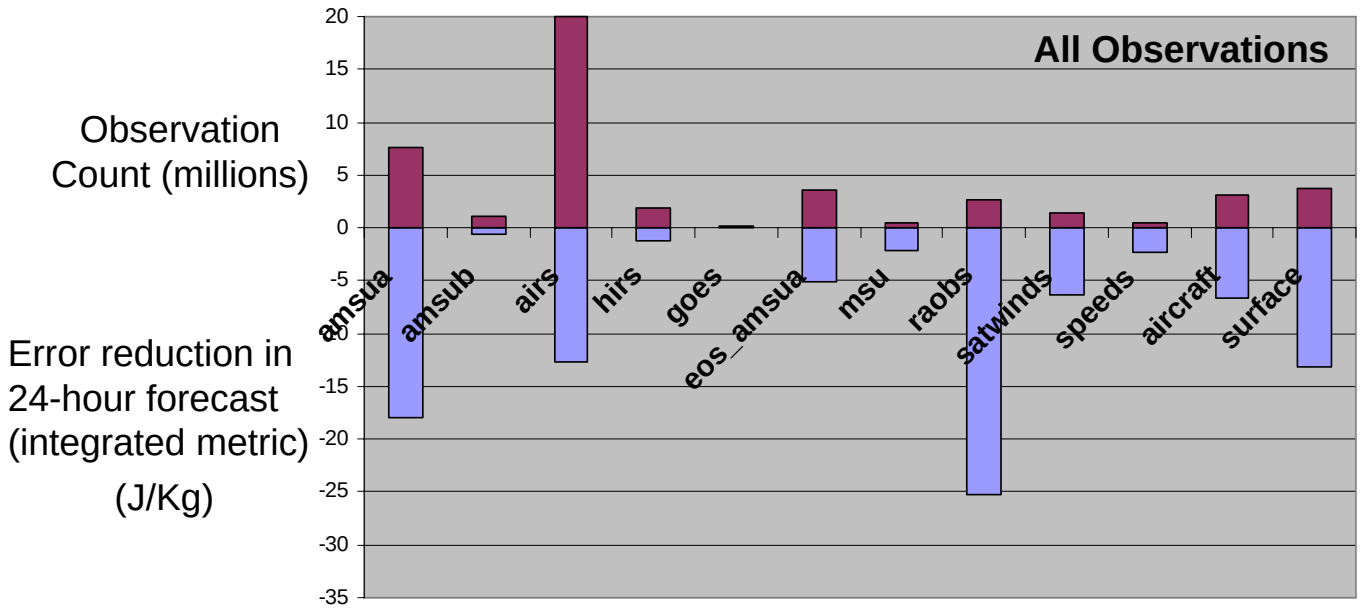


Observation sensitivity tools developed by the GMAO indicate that the some of the AIRS moisture channels have negative impact on forecast skill

AIRS brings slightly positive impact on forecast skill in Northern Hemisphere; clear positive impact in Southern Hemisphere. But forecast skills are increased when moisture channels from AIRS are not included

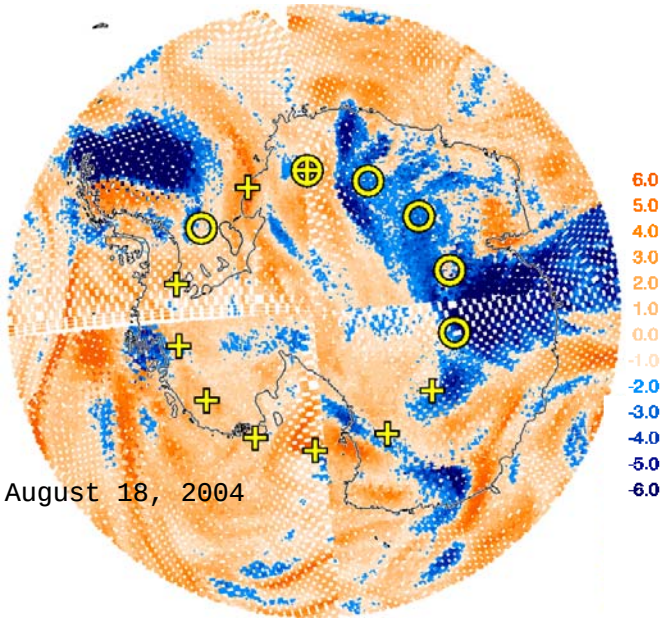
GEOS-5 Observation Impact: July 2005 00z Totals

Ron Gelaro and Yanqiu Zhu

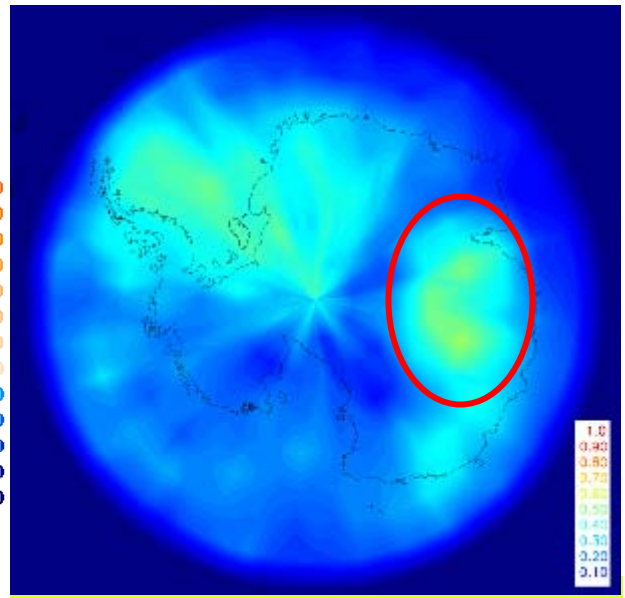


Ice Polar Stratospheric Clouds (PSCs) Detected from Assimilation of AIRS Data

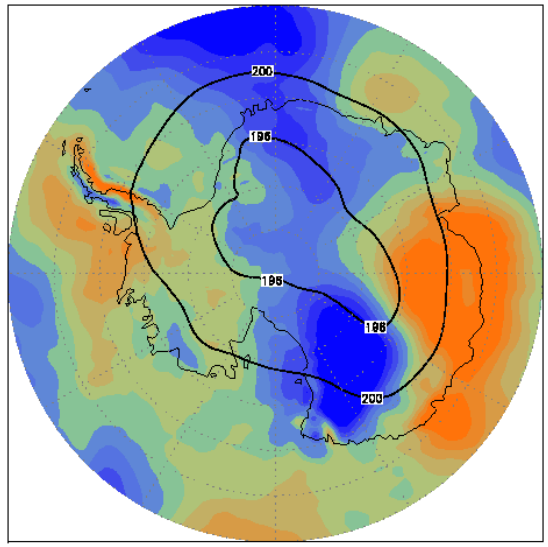
Ivanka Stajner



AIRS observations-minus-**GEOS-5** forecast (O-Fs) for 6.79μm "moisture" channel. The forecast is computed assuming that clouds are not present. O-Fs lower than –2K (blue) typically coincide with locations where POAM III detected ice PSCs (◎).



High frequency of AIRS O-Fs lower than -2K indicates frequent ice PSCs in an unusual region during August 2004.



This is a cold region (temperature contours) with frequent upwelling (orange) during August 2004 at 200 hPa over Antarctica.

I. Stajner, C. Benson, H.-C. Liu, S. Pawson, N. Brubaker, L.-P. Chang, L. P. Riishojgaard and R. Todling (GMAO). Manuscript submitted to *Geophysical Research Letters*.

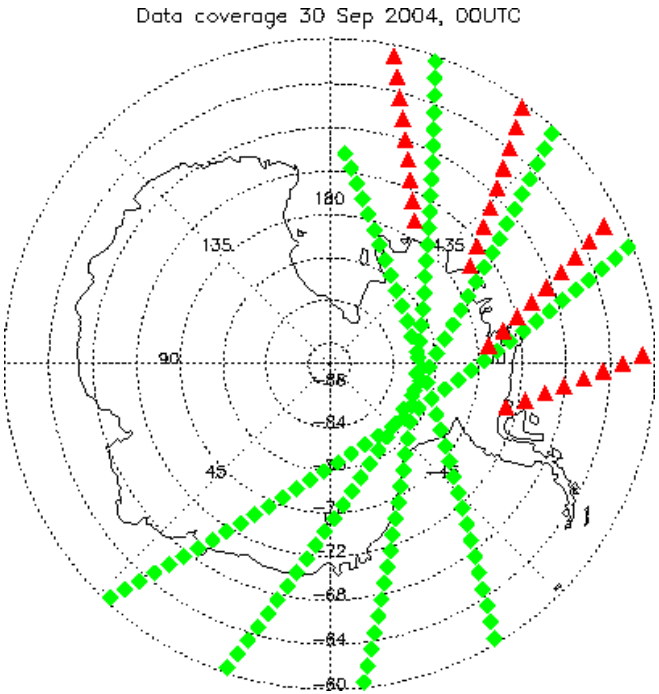
Contact: ivanka@gmao.gsfc.nasa.gov

Assimilating AURA/MLS ozone

Meta Sienkiewicz and Ivanka Stajner

SBUV daytime only – no data near South Pole due to high solar zenith angle

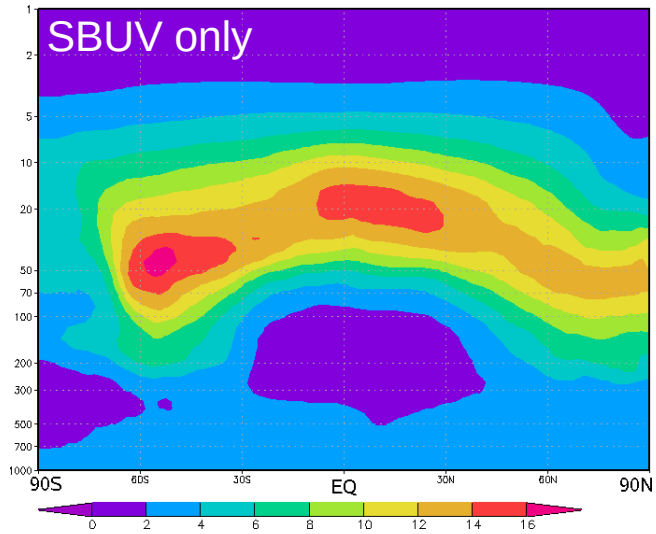
MLS orbital limit ±82º

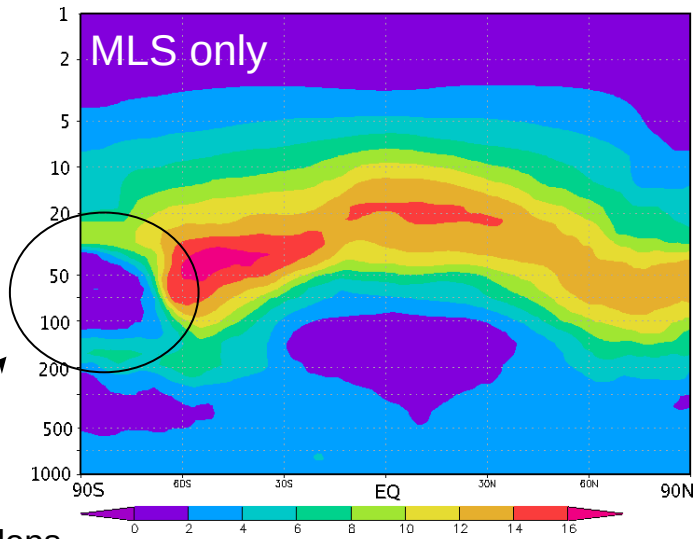


▲ NOAA 16 SBUV

◆ MLS

Zonal mean ozone 9/30/2004 00UTC



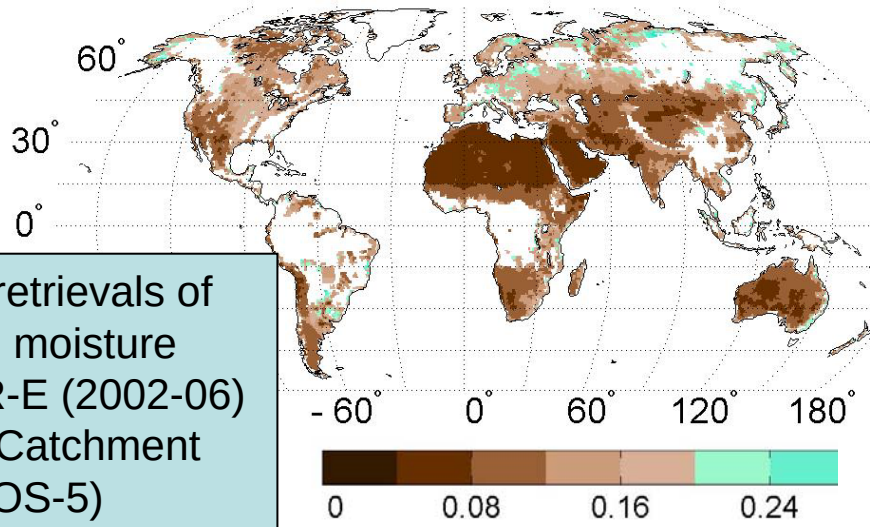


Ozone hole develops in MLS assimilation

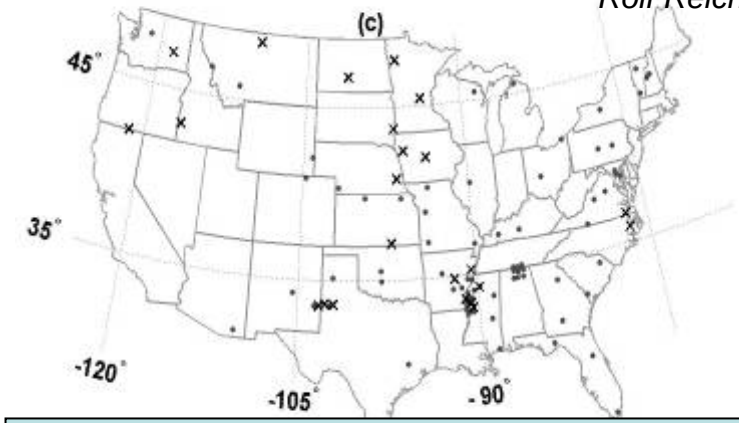
Ozone partial pressure (mPa)

Global assimilation of AMSR-E soil moisture retrievals

Rolf Reichle



Assimilate retrievals of surface soil moisture from AMSR-E (2002-06) into NASA Catchment model (GEOS-5)



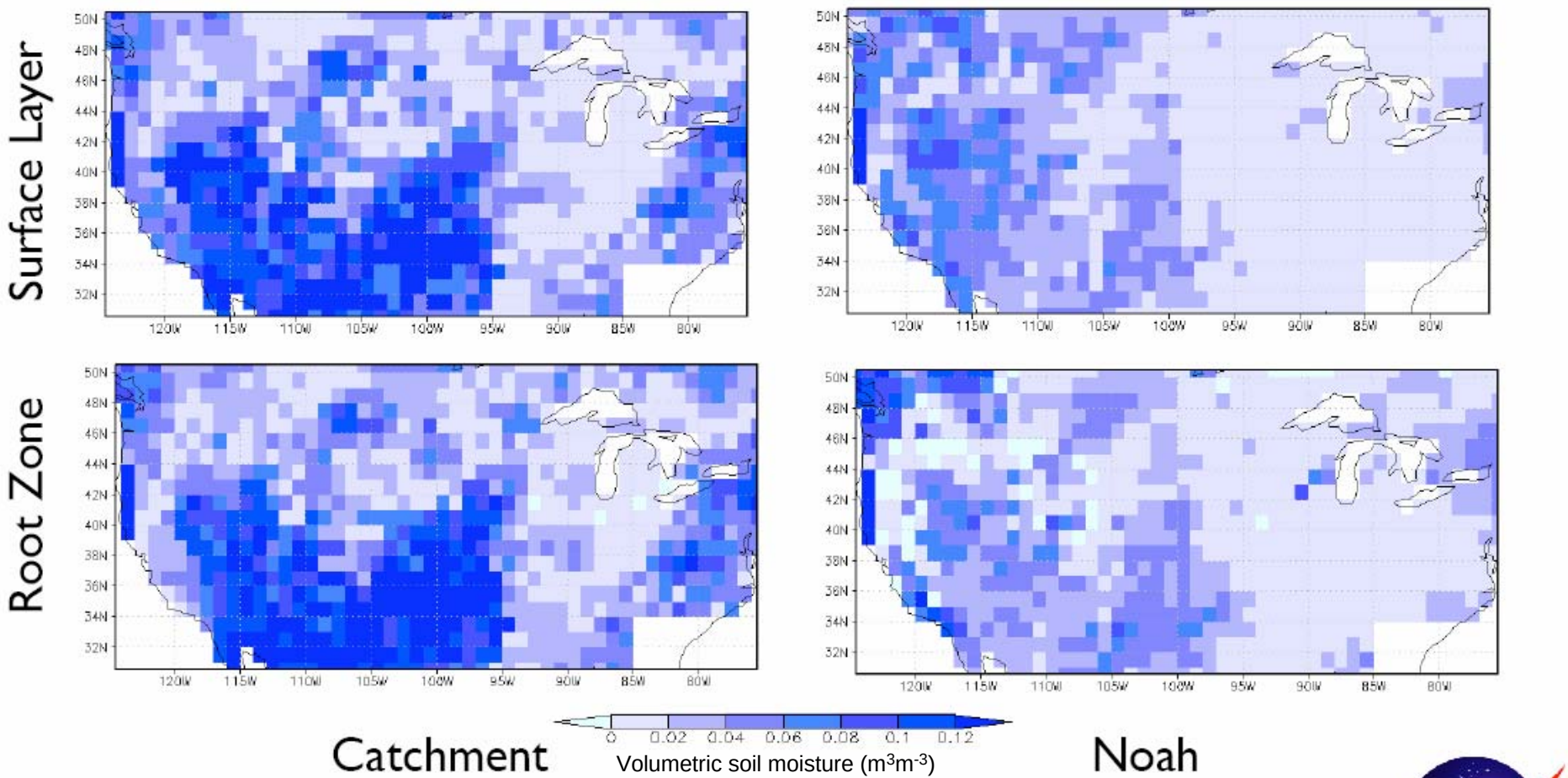
Validate with USDA SCAN stations (only 23 of 103 suitable for validation)

Reichle et al. ***JGR*, 2007**		Anomaly time series correlation coeff. with in situ data [-] (with 95% confidence interval)			Confidence levels: Improvement of assimilation over	
	N	**Satellite**	**Model**	**Assim.**	**Satellite**	**Model**
Surface soil moisture	23	**.38±.02**	**.43±.02**	**.50±.02**	**>99.99%**	**>99.99%**
Root zone soil moisture	22	**n/a**	**.40±.02**	**.46±.02**	**n/a**	**>99.99%**

Assimilation product agrees better with ground data than satellite or model alone.

Modest increase may be close to maximum possible with *imperfect* in situ data.

Improvement Metric (RMSE(OpenLoop) - RMSE(EnKF)) for soil moisture OSSEs



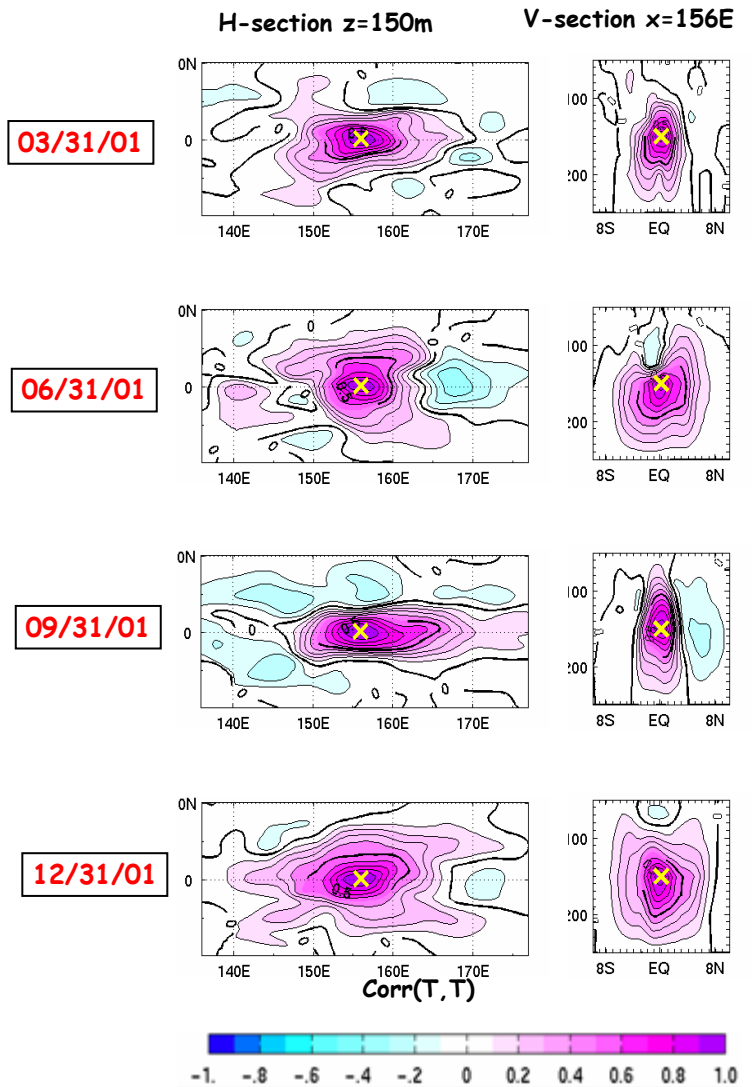
Kumar, Reichle, et al. (2007), *Adv. Water Resources,* in preparation.

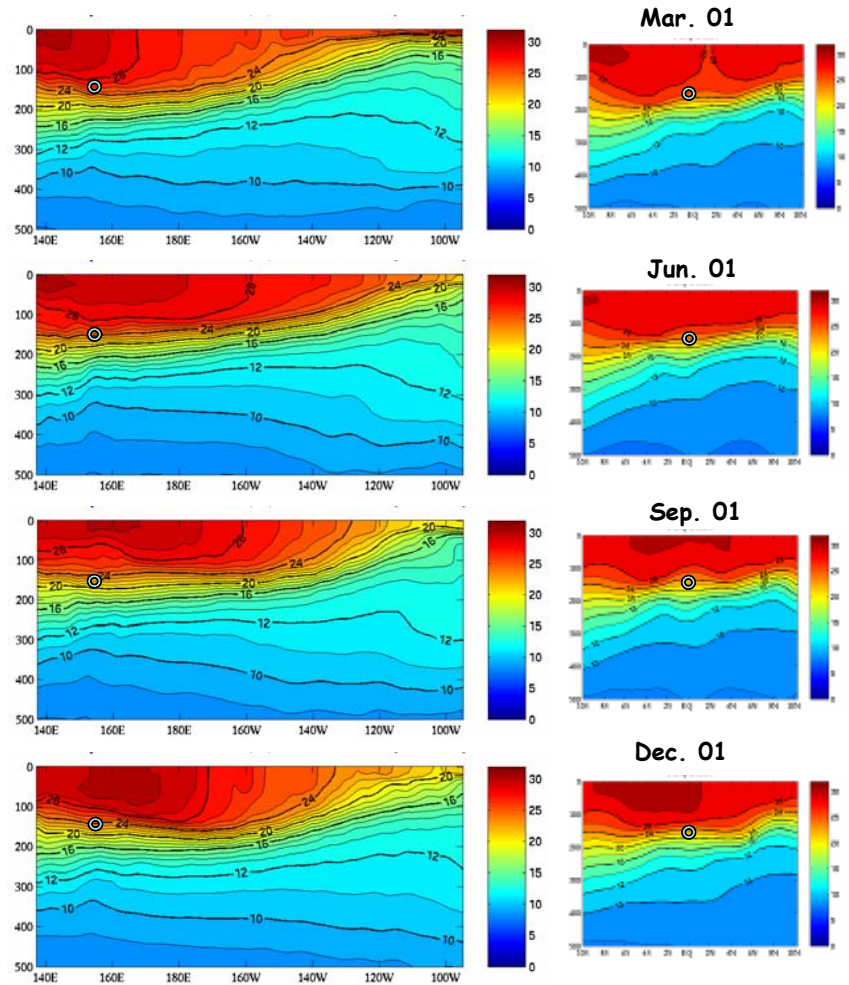
Ocean state-dependent covariances with the EnKF

Temporal evolution of Kalman gain for T obs.

Christian Keppenne

EnKF-33: filter
Schur(C,P) @(0N,156E,150m)





Impact of altimetry on seasonal forecasts

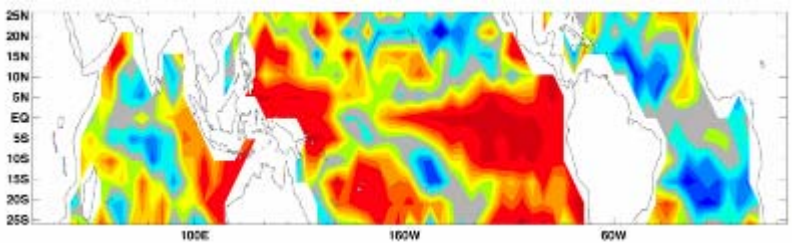
Anomaly correlation of forecast SSH with TOPEX data
May starts (1993-2001)

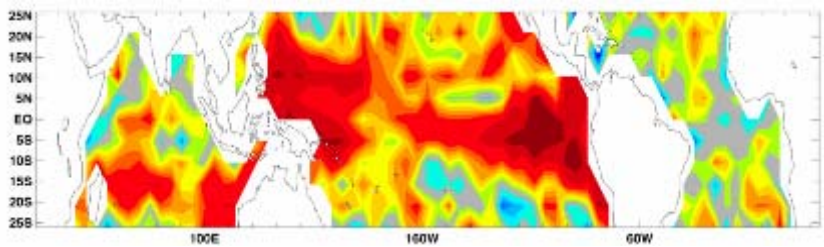
Forecast Lead

Altimeter data not used in initialization

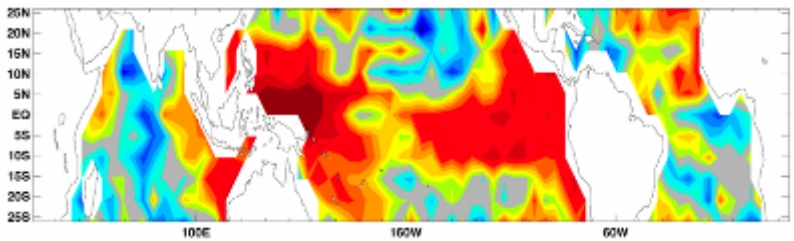
Altimeter data used in initialization

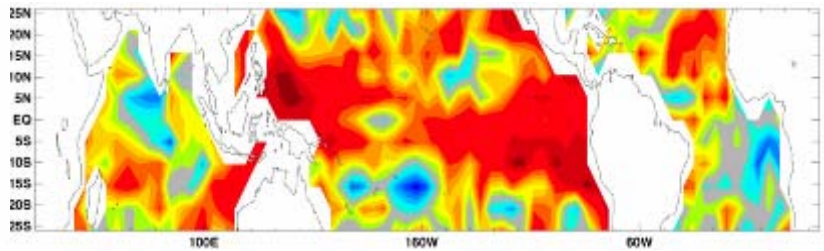
3 months

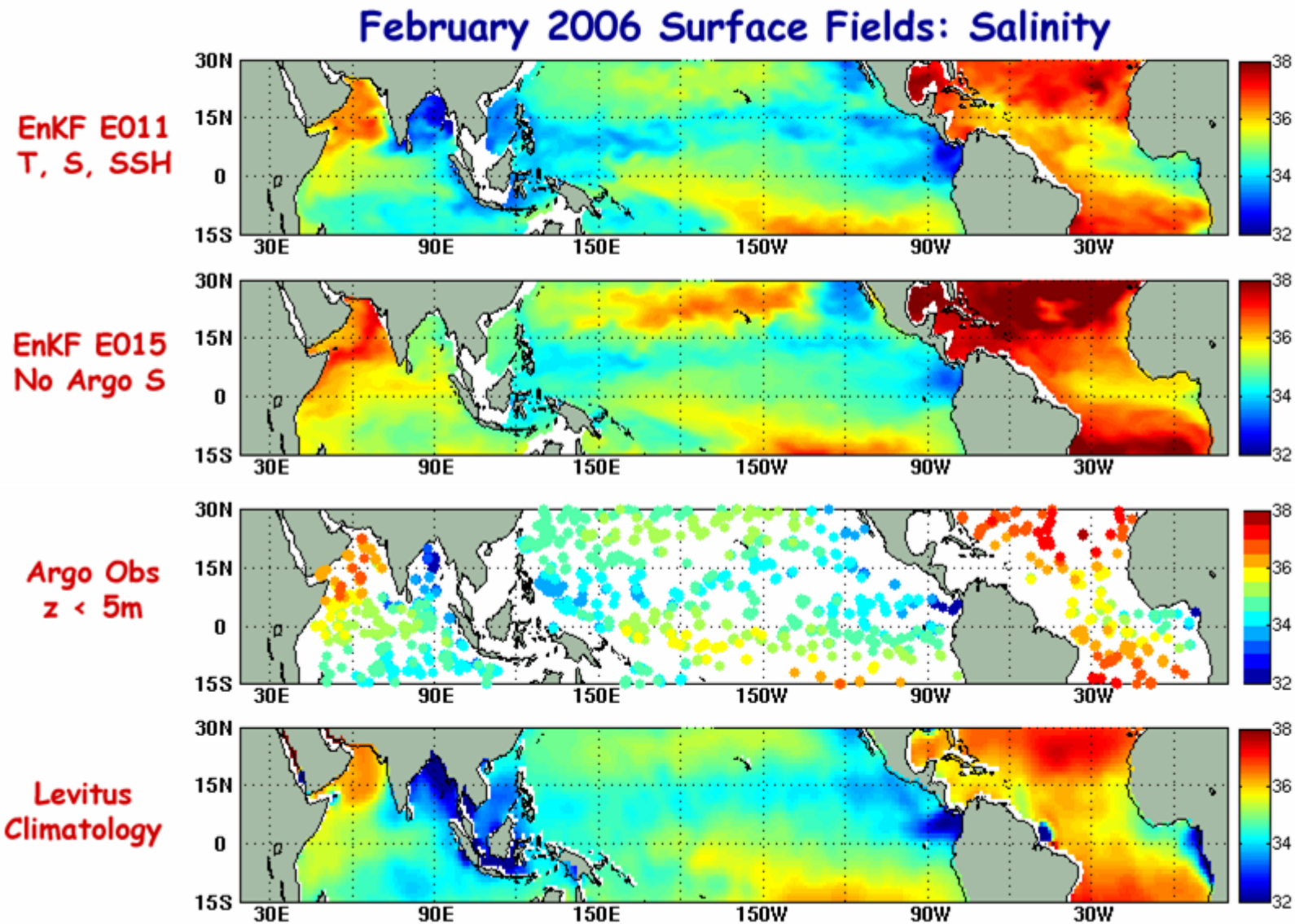




6 months






February 2006 Surface Fields: Salinity
EnKF E011
T, S, SSH
EnKF E015
No Argo S
Argo Obs
z < 5m
Levitus
Climatology
30N
15N
0
15S
30E
90E
150E
150W
90W
30W
38
36
34
32

GMAO's Collaborations with JCSDA Partners

- Atmosphere:-
  - GSI - NCEP
  - Adjoint tools - NRL
  - Ozone
  - OSSEs (emerging) - NCEP, NESDIS, et al
- Land Surface:-
  - EnKF development
  - LIS implementation for Catchment and Noah LSMs
- Ocean:-
  - EnKF and MvOI development for MOM4 - NCEP
  - Altimetry with online-bias-estimation
  - Ocean color